Experimental Stocking of American eels in the Susquehanna River Watershed

2011 Annual Report

Mitigation Project for: **City of Sunbury, Riverbank Stabilization Project**
DA Permit Application Number: NAB 2005-02860-PO5

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INTRODUCTION

American eel populations have been declining along the Atlantic coast. Although the Chesapeake Bay and tributaries support a large portion of the coastal eel population, the Susquehanna River comprises 43% of the Chesapeake Bay watershed and until recently was devoid of eels above Conowingo Dam. Construction of large mainstem dams in the 1900's effectively closed the river to upstream migration of juvenile eels (elvers) (Figure 1). Before dams were constructed, the annual harvest of silver eels in the Susquehanna River was nearly one million pounds. Although eels were stocked in the Susquehanna and its tributaries sporadically from 1938 to 1980, there is currently no commercial harvest or recreational fishery for eels. Dams on the Susquehanna River not only eliminated a once abundant eel fishery; they likely had a profound effect on the way the ecosystem functions. American eels, top predators in many streams, are estimated to have once comprised almost 25% of the fish biomass in most Atlantic slope streams and rivers. In addition, eels may be an important link to freshwater mussel populations.

Research conducted by the U.S. Geological Survey (USGS), Northern Appalachian Research Laboratory (NARL) and the U.S. Fish and Wildlife Service (USFWS), Maryland Fishery Resources Office (MFRO) indicates that American eel is the primary host fish for the freshwater mussel, *Elliptio complanata* (eastern elliptio) in the Susquehanna River (Lellis 2002, USGS NARL, unpublished data 2008). The larvae (glochidia) of freshwater mussels must parasitize a host fish to complete metamorphosis to the independent juvenile life stage. Glochidia from eastern elliptio collected in the Susquehanna River have higher metamorphosis success rates on American eels (55-98% success) than on other fish species found in the Susquehanna River. While eastern elliptio is the most abundant and widespread freshwater

mussel species in northeastern America, there are fewer eastern elliptio in the Susquehanna River watershed than nearby watersheds. In some streams and rivers, they comprise the most abundant biomass of any fauna in a watershed and can provide great filtration capacity. For example, the estimated 280 million eastern elliptio in the Delaware River have the potential to filter 2 billion to 6 billion gallons of water and remove 78 tons of sediment from the water column each day (Spooner and Lellis 2010). If eels are the missing link to abundant freshwater mussel populations in the Susquehanna River, restoring eels could also restore this fauna, which could result in improved water quality in the system.

After the 1928 construction of Conowingo Dam near the mouth of the Susquehanna River, access for eels to 400 miles of the Susquehanna watershed drastically declined. Mainstem Susquehanna River fish passage facilities (lifts and ladder) were designed and sized to pass adult shad and herring and are not effective (due to attraction flow velocities and operating schedules) in passing elvers upriver. Specialized passages designed to accommodate eels are needed to allow them access to the watershed above dams. Low recruitment of eastern elliptio could be linked to the lack of eel passage over dams in the mainstem Susquehanna River. In order to test this hypothesis and as mitigation for the City of Sunbury, Riverbank Stabilization Project, the objectives of this project are to:

1. Stock juvenile American eels (elvers) in upstream tributaries to the Susquehanna River with existing eastern elliptio populations (Buffalo Creek, Union County, PA, and Pine Creek, Tioga County, PA).
2. Encourage larval eastern elliptio attachment on a subset of reintroduced eels through tank culture techniques.
3. Monitor eel presence/absence at 2 sites in each tributary during each of the three years of stocking (2010, 2011, and 2012) and 5 years (2014) and 10 years (2019) after the first eel introduction.
4. Survey freshwater mussel populations in each tributary to collect baseline mussel population data and to assess recruitment to the mussel populations 5 years (2014) and 10 years (2019) after the first eel reintroduction.

METHODS

Eastern Elliptio Glochidia Transformation

In May and June of 2011, methods for transforming eastern elliptio glochidia to juveniles through attachment to elver gills were tested at the USFWS MFRO laboratory in Annapolis, MD. Eastern elliptio were collected from Andover Branch (tributary to the Chester River, Queen Anne's County, MD), Deer Creek (tributary to the Susquehanna River, Harford County, MD), and Buffalo Creek. Eels were collected using a backpack electrofishing unit in Octoraro Creek (tributary to the Susquehanna River, Cecil County, MD).

In the laboratory, we induced release of glochidia in eastern elliptio by increasing water temperatures to 18°C. Viability of glochidia collected from tanks was tested by exposing a subsample of glochidia to salt; those that snapped shut in response were considered viable (Zale and Neves 1982). To infect fish, we introduced eels to water baths (17.0-18.5°C) containing glochidia. At each infection event, glochidia in three samples of the glochidia bath were counted to provide an estimate of glochidia per liter. After approximately 30 minutes, fish were transferred to a second water bath (without glochidia) for 30 minutes so that glochidia that were not fully attached could be washed off. Eels were then transferred to 1 liter plastic aquaria (Aquatic Habitats ® (AHAB)) where they were monitored for the remainder of the experiment (30 days). Aquaria were siphoned approximately three times each week until one week after the last juvenile mussel was found to ensure no glochidia or juveniles went undetected. After siphoning, collected material from each aquarium was transferred to a Petri dish, and contents were observed under a dissecting scope. Juvenile mussels were identified by their opaque shells and presence of a foot. The number of glochidia or transformed juvenile mussels was recorded. The mean number of transformed juveniles was calculated (± S.D.) for the number of eels

remaining at the end of each trial. In addition, a transformation rate, expressed as a percentage, was calculated (± S.D.) using the number of glochidia that detach after at least one day of attachment (G) and the number of transformed juveniles (J).

$$\text{Transformation Rate} = 100 \times (J / J+G)$$

Results will aid in the estimation of the number of mussels capable of being transformed from glochidia to juveniles on the gills of elvers.

In addition to experimental infection, eels were collected from Buffalo Creek using a backpack electrofishing unit when the water temperature was 20°C. Captured eels were transported live to the USFWS MFRO Laboratory for analysis. One eel was sacrificed and gills removed for examination under the dissecting microscope. Two eels were placed in buckets until individual aquaria became available. Buckets and aquaria were siphoned to detect juvenile mussels.

Eel Stocking

Based on eel data (number of eels per km) collected in tributaries to the Susquehanna River and Chesapeake Bay below Conowingo Dam, a rough estimate of capacity for eels in upstream tributaries was calculated. An average density of eels was estimated at 529 eels/km using data collected by Maryland Department of Natural Resource (MD DNR), Maryland Biological Stream Survey (MBSS), in four tributaries downstream of Conowingo Dam: Big Elk Creek (Cecil County, MD), Furnace Bay (Cecil County, MD), Little Elk Creek (Cecil County, MD), and Northeast River (Cecil County, MD). The number of eels needed to achieve a similar density of 529 eels/km at stocking sites was calculated by multiplying the number of mainstem stream kilometers above the stocking site by the average density. Based on these calculations

and the projected feasibility of capturing eels for stocking, we proposed to relocate up to 60,000 eels to each of Buffalo Creek and Pine Creek over a three year period (2010 through 2012).

The MD DNR is required by the Atlantic States Marine Fisheries Commission (ASMFC) to conduct Young-of-Year (YOY) eel monitoring. Their sampling device is located at a bridge culvert in Turville Creek (Ocean City, MD). In April of 2011, MD DNR personnel collected glass eels which were then transported by the USFWS and the Tiadaghton Audubon Society to the USGS NARL in Wellsboro. Glass eels were held in captivity at the lab until June of 2010. Eels were then stocked at 5 locations (Table 2).

American eel elvers (90-150 mm) were collected by the USFWS using a collection device located immediately downstream of Conowingo Dam. An eel ramp consisting of cable tray, covered and lined with Enkamat, was deployed at the base of Conowingo Dam. Water from the Susquehanna River was pumped to the top of the cable tray ramps where it flowed down the Enkamat to attract elvers. Elvers crawled up the ramps and were swept into fine meshed collection bags inside 80 gallon cattle tanks. Aerated water was circulated through the collection tanks to keep elvers in good health. Captured elvers were sedated, measured, and counted. Large numbers of eels were estimated volumetrically. Transported eels were marked using buffered oxytetracycline (OTC) at a concentration of 550 ppm for 5 hours prior to release.

Captured eels were stocked in two tributaries to the Susquehanna River in the vicinity of eastern elliptio beds to encourage additional association between eastern elliptio glochidia and eels (Figure 2). One tributary, Buffalo Creek, has a relatively high density of eastern elliptio. The mouth of Buffalo Creek, near Lewisburg, PA is approximately 9 miles north of Sunbury, PA on the West Branch of the Susquehanna River. Eels were stocked near high densities of eastern elliptio in 2 locations, Strawbridge Rd. Bridge (40.9856 N, 76.93237 W) and the footbridge on

Rt. 1003 (40.98105 N, 76.95134 W). A second tributary, Pine Creek, located north of Jersey Shore, PA on the West Branch of the Susquehanna River, has the highest density of eastern elliptio found in our surveys in the Susquehanna River watershed. However, almost all of the eastern elliptio found in Pine Creek are older adults. Eels were stocked near high densities of eastern elliptio in 4 locations, Owassee Rapids (41.71568 N, 77.45543 W), Darling Run Access (41.74368 N, 77.43394 W), Marsh Creek Boat Ramp (41.74466 N, 77.42775 W), and Ansonia Bridge (41.73671 N, 77.43036 W). Conowingo Creek (Lancaster County, PA) just above Conowingo Dam serves as a backup stocking location. Elvers collected in batches too small for transport to Buffalo or Pine Creek were stocked in Conowingo Creek at the Mason Dixon Bridge (39.73075 N, 76.17836 W). Stockings conducted in 2011 were documented and reported to the Pennsylvania Fish and Boat Commission as part of the requirements of the Scientific Collecting Permit Number 354, Type 2.

Fish survey

To evaluate stocking success, including survival, growth and habitat use, as well as to document the fish community, we conducted electrofishing surveys using 5 backpack electrofishing units in August and September of 2011. Methods used by the MDDNR MBSS (2007) were used to quantify the catch per unit effort (CPUE) and the biomass of eels. Two sites, bracketing the eel release sites, in each stream were surveyed. At each site, 75 meters of stream was blocked off using ¼" block net. In order to get a complete picture of the fish community in each stream, 2 passes with the electrofishing units were conducted and all fish collected were enumerated. Captured eels were measured to assess growth and a subsample of the eels collected was brought back to the lab to assess otoliths to verify that eels were marked with OTC. Mass (kg) of the total catch and of eels captured was measured to assess changes in

biomass of eels over time. Population estimates were calculated using the methods of Seber and LeCren (1967).

Mussel survey

No mussel surveys were conducted in 2011 as part of this project. Baseline mussel data were collected during mussel surveys conducted in Buffalo Creek in July of 2010. Data collected during mussel surveys conducted by USGS NARL in 2008 in Pine Creek as part of another project, using identical methods to those used in Buffalo Creek, were used as baseline data for this project. Mussel surveys will be conducted again in 2014.

RESULTS

Eastern Elliptio Glochidia Transformation

In 2011, 30 elvers (90-150 mm) were infected with eastern elliptio glochidia in three separate trials. Over 1322 eastern elliptio transformed from glochidia to juveniles on 22 elvers during the experiment. Despite attempts to apply screens to aquaria, only 63% of the eels in the study remained in their aquaria for the duration of the study. For the 19 eels that remained in the tanks until the end of the three trials, the mean number of juveniles transformed per eel was 87.6 (S.D. ± 63.3) and the mean transformation rate was 97.8% (S.D. ± 2.8). Information about the individual trials can be found in Table 1.

Eel Stocking

Of the 75,000 glass eels collected and held in captivity, an estimated 64,000 survived to the elver stage, were OTC marked and stocked at 5 locations in Pine Creek and Buffalo Creek (Table 2). All glass eels were certified disease free by USFWS Lamar Fish Health Center (Lamar, PA) prior to release. In Pine Creek, 32,000 glass eels were released at 3 sites (Owassee

Rapids, Darling Run Access, Ansonia Bridge). In Buffalo Creek, 32,000 glass eels were released at two stocking sites (Figure 2).

During June, July, and August of 2011, an estimated 84,961 elvers (average length 127 mm) were captured in the Susquehanna River below Conowingo Dam. A sample of elvers was certified disease-free by the USFWS Lamar Fish Health Center. An estimated 52,298 elvers captured below the dam were marked with OTC and stocked in Buffalo and Pine Creeks (Table 2). In addition, 9,641 elvers were stocked in Conowingo Creek.

Fish Survey

During electrofishing surveys in August and September of 2011, 441 eels were recaptured in Buffalo Creek and 20 eels were recaptured in Pine Creek (Table 3). Three of the four sites (Darling Run Access and Ansonia Bridge in Pine Creek and Strawbridge Rd Bridge in Buffalo Creek) were surveyed in August. Due to inclement weather in late August and early September, the fourth site (Footbridge on Rt 1003 in Buffalo Creek) was not surveyed until late September. Due to high flows, block nets could not be adequately placed at this site so a timed survey was conducted instead.

The lengths of the recaptured fish in Buffalo Creek were normally distributed with a mean of 136.7 mm (S.D. ± 24.0) and few large eels measuring over 250 mm (Figure 3a). Likely due to the smaller sample size, there was not a normal length distribution of eels captured in Pine Creek (Figure 3b). The mean length of recaptured eels in Pine Creek was 142.8 mm (S.D. ± 39.7). The 441 recaptured eels in Buffalo Creek had a total mass of 2.04 kg resulting in an average of 4.6 g per eel and comprised 9.5% of the total biomass of captured fish. The 20 recaptured eels in Pine Creek had a total mass of 91 g resulting in an average of 4.5 g per eel and comprised 0.8% of the total biomass of captured fish. Density was calculated for all sites but the

Footbridge at Rt 1003 on Buffalo Creek and a sufficient depletion to calculate abundance was achieved at only two sites (Buffalo Creek, Strawbridge Rd. Bridge and Pine Creek, Darling Run Access) (Table 4).

In addition to eels, 5514 individuals of 29 fish species were collected in Buffalo Creek and 3645 individuals of 24 fish species were collected in Pine Creek during electrofishing surveys (Table 3). Relative abundance by family indicates that eels make up a greater proportion of the population in Buffalo Creek than Pine Creek (Figure 4). From 2010 to 2011 relative abundance of eels increased in Buffalo Creek from 5.6% to 7.6% and in Pine Creek from 0 to 0.6%.

DISCUSSION

During the second year of this project we exceeded our 3 year stocking goal of 60,000 eels in each of Buffalo Creek (71,412 eels) and Pine Creek (78,979 eels). We also completed electrofishing surveys in both Pine Creek and Buffalo Creek. Our success in recapturing over 400 eels in Buffalo Creek and 20 eels in Pine Creek indicates that the stocked elvers and glass eels are remaining near the stocking site. At the Strawbridge Rd Bridge site, the eels have remained near the stocking site at a fairly high density (0.17 eels / m^2).

As expected, the relative abundance of eels increased from 2010 to 2011. However, the density of eels at survey sites is much higher in Buffalo Creek than Pine Creek Reasons for this may include timing of stockings and size of the tributary. Although the two streams have been stocked with a similar number of eels, much of the stocking in Pine Creek occurred in late August and early September, after 2011 surveys occurred. Catch rates at Conowingo Dam increased dramatically following record rainfall in the Susquehanna River Basin due to

Hurricane Irene and Tropical Storm Lee. A large number of the eels captured during late August and early September were stocked in Pine Creek at Ansonia Bridge.

While we expect elvers to move upstream during spring and summer months, this is not always the case with stocked eels (Berg and Jorgensen 1994). Buffalo Creek is relatively short and not as wide in comparison with Pine Creek, giving eels fewer options for distribution within the watershed. At its confluence with the Susquehanna River, Pine Creek is a 6th order stream. Eels are stocked relatively high in the watershed but there are still 124 mainstem km in Pine Creek above the primary stocking site (Ansonia Bridge). In comparison, Buffalo Creek is a 4th order stream at its confluence with the Susquehanna River and while eels are stocked low in the Buffalo Creek watershed there are only 30 mainstem km in Buffalo Creek above the primary stocking site (Strawbridge Rd. Bridge). According to Smogor et al. (1995), natural eel density may not be as high in headwater streams (stream order 1-3) as those tributaries in closer proximity with the ocean. However, it is difficult to know if lower density is due to eel preference or because it is a longer journey to reach headwater streams. If we assume that the 78,979 eels stocked in Pine Creek move primarily upstream, there are many more stream km to encounter before overcrowding occurs. In Buffalo Creek however, the 71,412 stocked eels may encounter competition upstream so stay closer to the stocking site and may be moving downstream of the stocking site.

In laboratory trials conducted at MFRO in 2011, the average number of eastern elliptio juveniles transformed was over 87 mussels per eel. A similar number of juveniles were transformed in host fish trials completed by USGS NARL (81 mussels per eel) (personal communication, Bill Lellis, USGS, NARL). The eel captured in Buffalo Creek in June of 2011 from which we removed the gills and examined encysted glochidia, looked as if it would yield

20 juvenile mussels. In areas throughout Buffalo and Pine Creeks where eel densities are high and eastern elliptio are present, we would expect a yield of juvenile mussels between 20 and 87 juveniles per eel.

There appears to be a relationship between the four years of elver capture data below Conowingo Dam and the glass eel (Young-of Year) index conducted on Turville Creek in Ocean City, MD (Figure 5). Catch rates for elvers at Conowingo Dam reflect recruitment of glass eels one year earlier at Turville Creek. In 2011 the number of elvers at Conowingo Dam was higher than expected. A large number of eels were captured during high flows in August and September. Based on the catch rate in Turville Creek in 2011, we expect to catch a smaller number of eels at Conowingo Dam in 2012.

In the coming year, we plan to maximize our stocking effort in Pine Creek by stocking it with the majority of the elvers captured at Conowingo Dam. A smaller number of eels will be stocked in Buffalo Creek. In 2012, we again expect to stock eels collected as glass eels from Ocean City in each of Buffalo Creek and Pine Creek. Glass eels will again be held at the USGS NARL. A subsample of elvers collected at Conowingo Dam will be infected with glochidia and released.

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Table 1. Number of eastern elliptio glochidia per liter in 6 liter infection baths, number of eels at the start (n_1) and end (n_2) of each trial, mean number of juveniles transformed per eel ± S.D., the total number of juveniles transformed, and the transformation rate ± S.D. at each trial beginning April 11, 2011 (trial 1), June 1, 2011 (trial 2), and June 3, 2011 (trial 3). Gravid female eastern elliptio were collected from Andover Branch, MD for trial 1, and Buffalo Creek, PA for trials 2 and 3.

Trial	glochidia per liter	n_1 (n_2)	mean juveniles per eel	total juveniles	transformation rate (%)
1	3,667	6 (3)	120.7 ± 66.5	362	97 ± 3.49
2	15,000	12 (8)	119.9 ± 87.6	959	97 ± 2.97
3	12,500	12 (8)	43.7 ± 23.5	352	98 ± 2.54

Table 2. Eels stocked in Buffalo Creek (Union County, PA), Pine Creek (Tioga County, PA) and Conowingo Creek (Lancaster County, PA) in 2010 and 2011.

Date	# Stocked	Location	Mean Length (mm)	Origin
		Pine Creek		
June 9, 2010	3,000	Darling Run Access	56.3*	Turville Creek
June 9, 2010	3,000	Ansonia Bridge	56.3*	Turville Creek
June 9, 2010	3,000	Owassee Rapids	56.3*	Turville Creek
June 21, 2011	10,666	Darling Run Access	80.1 ± 16.0	Turville Creek
June 21, 2011	10,666	Ansonia Bridge	80.1 ± 16.0	Turville Creek
June 21, 2011	10,668	Owassee Rapids	80.1 ± 16.0	Turville Creek
June 30, 2011	7,222	Marsh Creek Boat Ramp	127 ± 16.9	Conowingo Dam
August 22, 2011	1,528	Ansonia Bridge	127 ± 16.9	Conowingo Dam
August 31, 2011	8,940	Ansonia Bridge	127 ± 16.9	Conowingo Dam
September 2, 2011	8,084	Ansonia Bridge	127 ± 16.9	Conowingo Dam
September 7, 2011	12,205	Ansonia Bridge	127 ± 16.9	Conowingo Dam
Total	**78,979**			
		Buffalo Creek		
June 10, 2010	8,084	Strawbridge Rd. Bridge	127.7	Conowingo Dam
June 10, 2010	4,500	Strawbridge Rd. Bridge	56.3*	Turville Creek
June 10, 2010	4,500	Footbridge on Rt. 1003	56.3*	Turville Creek
June 21, 2010	7,790	Strawbridge Rd. Bridge	127.7	Conowingo Dam
June 21, 2011	16,219	Strawbridge Rd. Bridge	80.1 ± 16.0	Turville Creek
June 21, 2011	16,000	Footbridge on Rt. 1003	80.1 ± 16.0	Turville Creek
July 14, 2011	6,326	Strawbridge Rd. Bridge	127 ± 16.9	Conowingo Dam
July 18, 2011	4,390	Strawbridge Rd. Bridge	127 ± 16.9	Conowingo Dam
July 28, 2011	3,603	Strawbridge Rd. Bridge	127 ± 16.9	Conowingo Dam
Total	**71,412**			
		Conowingo Creek		
June 30, 2010	1,311	Mason-Dixon Bridge	127.7	Conowingo Dam
August 2, 2010	340	Mason-Dixon Bridge	127.7	Conowingo Dam
June 22, 2011	1,797	Mason-Dixon Bridge	127 ± 16.9	Conowingo Dam
September 8, 2011	7,844	Mason-Dixon Bridge	127 ± 16.9	Conowingo Dam
Total	**11,292**			

* length (mm) of glass eels was estimated using regression

Table 3. Number and catch per unit effort (CPUE, #/hour) of fish species captured in Buffalo Creek and Pine Creek during electrofishing surveys conducted in August and September of 2011.

	Buffalo Creek				**Pine Creek**			
	Strawbridge Rd Bridge		Footbridge on Rt 1003		Darling Run Access		Ansonia Bridge	
Shock time (hours)	5.9		0.9		4.8		4.5	
Common name	#	CPUE	#	CPUE	#	CPUE	#	CPUE
American eel	432	72.8	9	10.1	12	2.5	8	1.8
Northern hogsucker	144	24.3	20	22.5	35	7.3	19	4.2
Shorthead redhorse	1	0.2	-	-	-	-	-	-
White sucker	50	8.4	7	7.9	3	0.6	1	0.2
Rockbass	8	1.3	6	6.7	2	0.4	2	0.4
Redbreast sunfish	3	0.5	-	-	-	-	-	-
Pumpkin seed	26	4.4	7	7.9	-	-	-	-
Bluegill	-	-	2	2.2	-	-	1	0.2
Smallmouth bass	10	1.7	2	2.2	28	5.8	6	1.3
Central stoneroller	59	9.9	0	0.0	2	0.4	3	0.7
Rosyside dace	-	-	2	2.2	-	-	-	-
Spotfin shiner	4	0.7	1	1.1	-	-	2	0.4
Common carp	-	-	1	1.1	-	-	-	-
Cutlips minnow	58	9.8	14	15.7	157	32.7	81	18.1
Common shiner	34	5.7	-	-	14	2.9	17	3.8
Pearl dace	1	0.2	-	-	-	-	-	-
River chub	-	-	-	-	1	0.2	-	-
Golden shiner	8	1.3	-	-	-	-	-	-
Emerald shiner	16	2.7	-	-	-	-	-	-
Spottail shiner	2730	459.8	2	2.2	36	7.5	7	1.6
Swallowtail shiner	-	-	-	-	9	1.9	1	0.2
Rosyface shiner	104	17.5	-	-	848	176.4	222	49.5
Mimic shiner	147	24.8	8	9.0	15	3.1	-	-
Bluntnose minnow	552	93.0	7	7.9	69	14.4	46	10.3
Blacknose dace	14	2.4	-	-	56	11.6	10	2.2
Longnose dace	46	7.7	1	1.1	27	5.6	10	2.2
Fallfish	54	9.1	8	9.0	111	23.1	265	59.1
Yellow bullhead	-	-	2	2.2	-	-	-	-
Margined madtom	155	26.1	3	3.4	182	37.9	306	68.3
Greenside darter	44	7.4	7	7.9	107	22.3	67	14.9
Tessellated darter	214	36.0	27	30.3	279	58.0	145	32.3
Banded darter	155	26.1	8	9.0	129	26.8	174	38.8
Shield darter	58	9.8	24	26.9	110	22.9	58	12.9

Table 4. Density (# eels / m^2) of eels, estimated abundance (Seber and Le Cren 1967) of eels, and % biomass of the fish captured was made up of eels during 2011 electrofishing surveys in Buffalo Creek and Pine Creek.

	Buffalo Creek		**Pine Creek**	
	Strawbridge Rd Bridge	Footbridge on Rt 1003	Darling Run Access	Ansonia Bridge
Density (# eels/m^2)	0.17	n/a	0.004	0.003
Abundance	480.3	n/a	12.5	n/a
% Biomass	10.1	6.1	1.2	0.6

Figure 1. Susquehanna River watershed with the locations of the 4 hydroelectric dams, York Have, Safe Harbor, Holtwood Dam, and Conowingo Dam denoted by straight lines across the mainstem Susquehanna River.

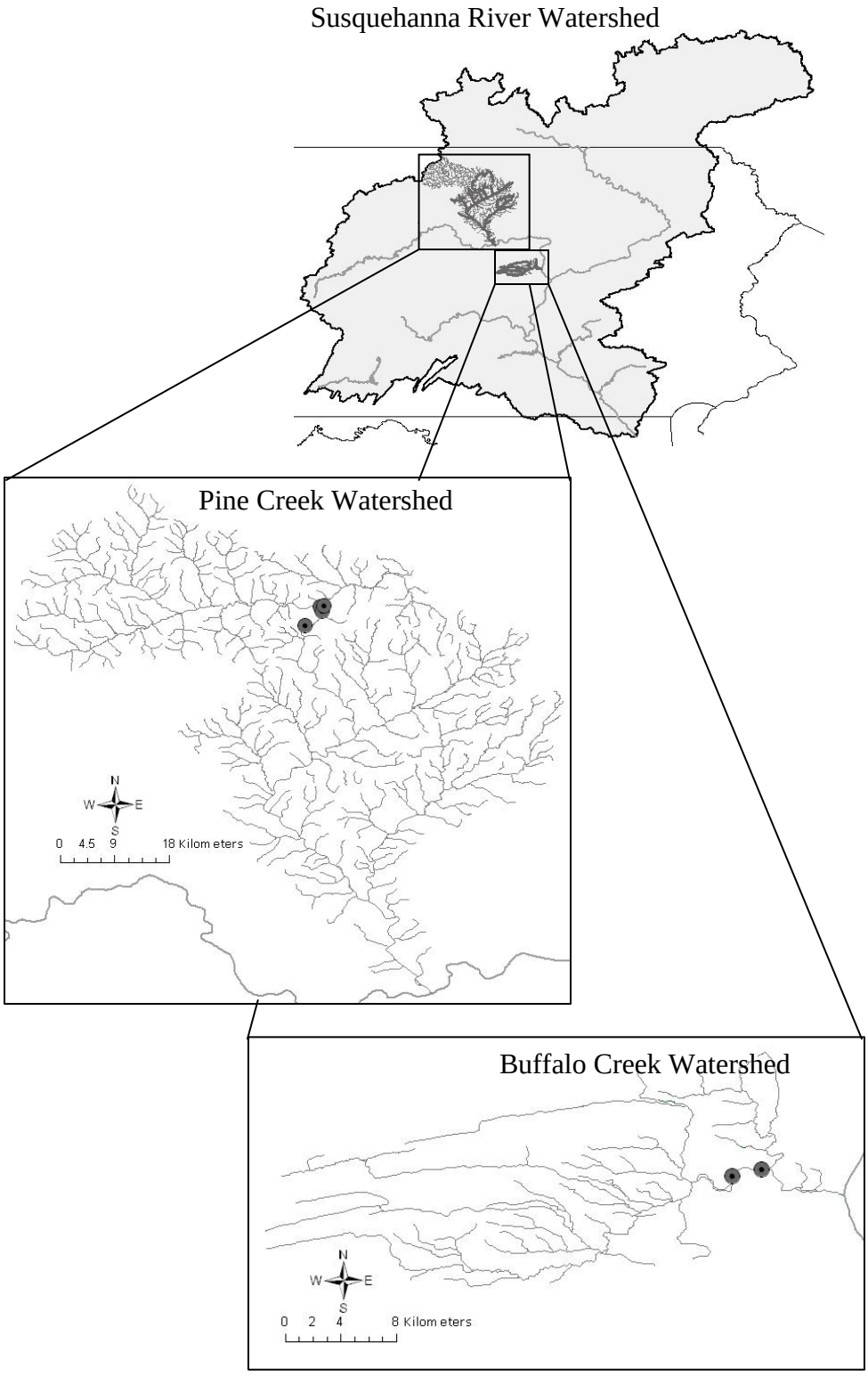
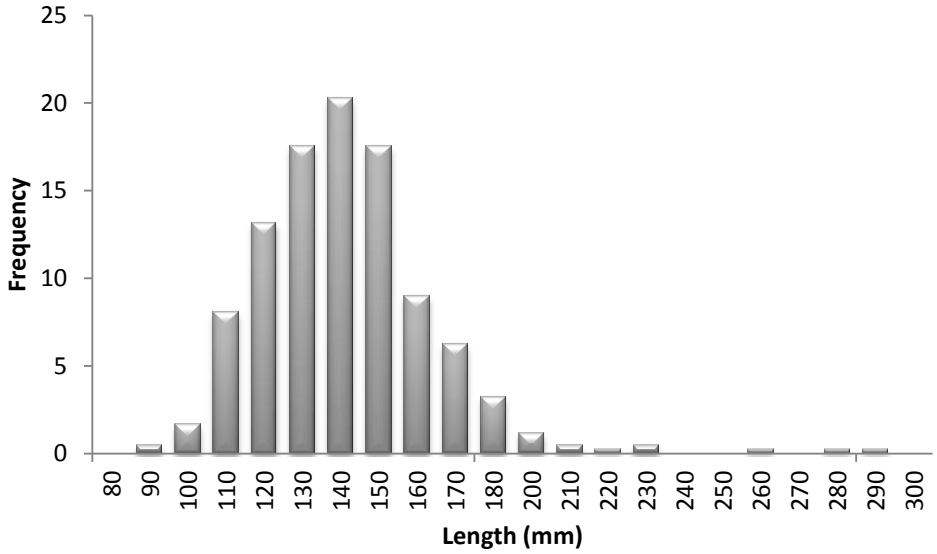


Figure 2. Eel stocking sites (indicated by dots) at Owassee Rapids, Darling Run Access, Marsh Creek, and Ansonia Bridge in Pine Creek (Tioga County, PA) and Strawbridge Rd. bridge and the footbridge at Rt. 1003 in Buffalo Creek (Union County, PA) in the Susquehanna River drainage.

Figure 3. Length frequency (expressed as percentage) of eels captured during monitoring surveys in (a) Buffalo Creek (n = 441) and (b) Pine Creek (n = 20) in September of 2011.

(a)



(b)

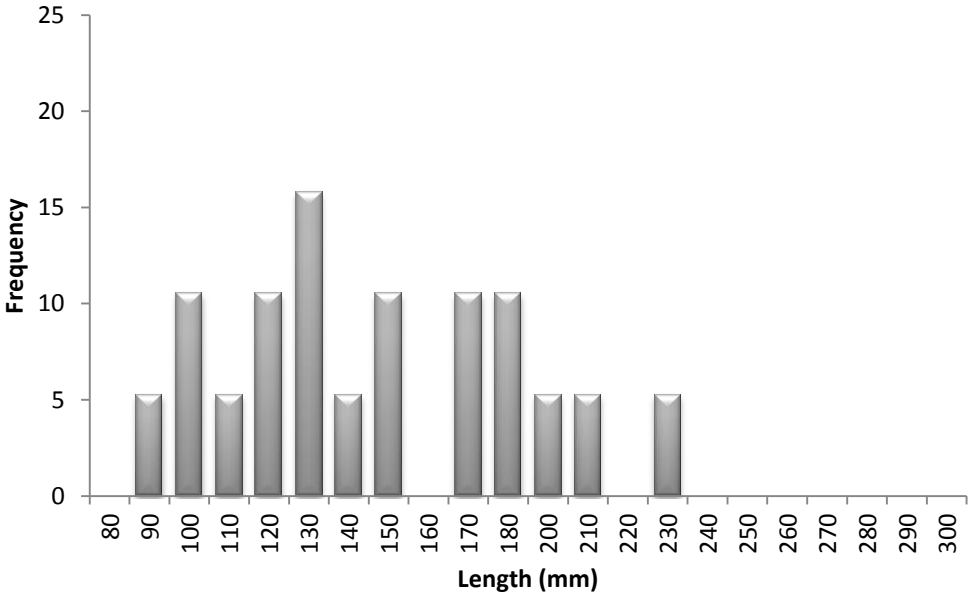


Figure 4. Relative abundance expressed as a percentage of 6 families of fish, Anguillidae (eels), Catastomidae (suckers), Centrachidae (sunfish and bass), Cyprinidae (minnows and shiners), Ictaluridae (catfish and madtoms), and Percidae (perch and darters) caught in Buffalo and Pine Creeks during backpack electrofishing in August and September, 2011.

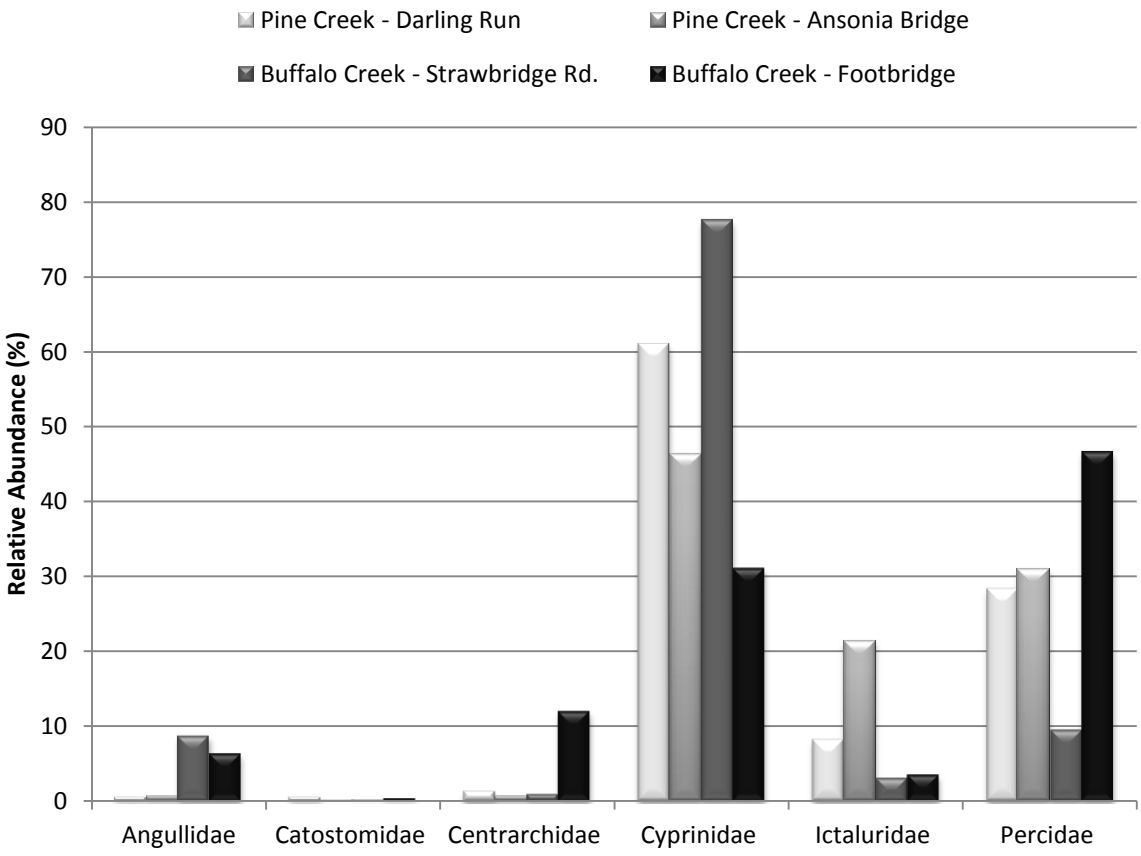
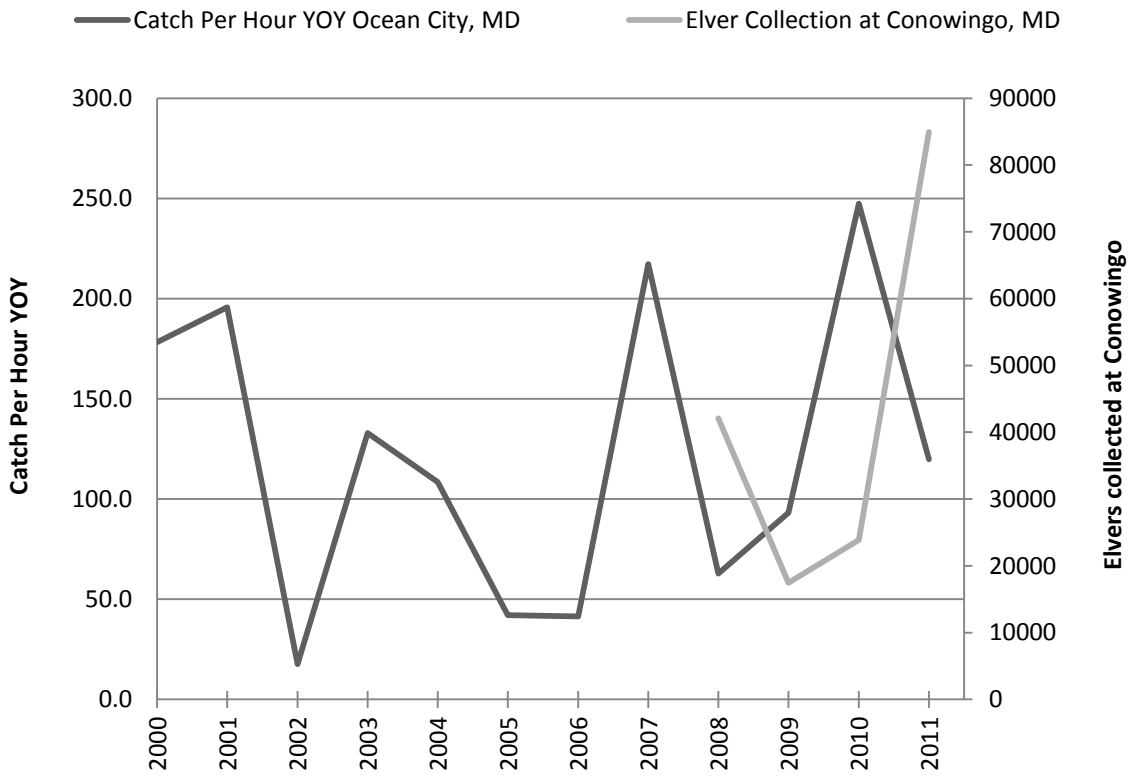


Figure 5. Glass eel (Young of Year (YOY)) catch per hour at the permanent sampling location in Turville Creek (Ocean City, MD) and the total number of elvers captured at the sampling location below Conowingo Dam on the Susquehanna River (Darlington, MD). The R^2 value was 0.789.



Appendix 1. American eels (*Anguilla rostrata*) were infected with larvae (glochidia) from the freshwater mussel, eastern elliptio (*Elliptio complanata*) during three trials in 2010 and 2011. After all eels in a trial were introduced to glochidia (infected) in 6 liters of water, individual eels were placed in 10 liter tanks. Tanks were siphoned 3 times a week for 35 days after infection. Proportion transformed is the proportion of transformed juveniles collected to the number of glochidia attached to the gills 1 day after infection.

Tank	Date Infected	Source of E. complanata glochidia	Number glochidia in 6 liters	Temperature Range (°C)	Number of glochidia	Number of days to siphoned glochidia	# transformed juvenile *E. complanata*	Number of days to siphoned juveniles	Proportion transformed
2	4/22/2011	Andover Branch	22,000	17.8 - 18.5	5	5	70	19	0.93
3	4/22/2011	Andover Branch	22,000	17.8 - 18.5	3	5	196	19	0.98
4	4/22/2011	Andover Branch	22,000	17.8 - 18.5	0	-	96	19	1.00
				Average	**2.67**	**5**	**120.7**	**19**	**0.97**
				Total	**8**		**362**		
17	6/1/2011	Buffalo Creek	90,000	18.2-19.5	0	-	265	16	1.00
18	6/1/2011	Buffalo Creek	90,000	18.2-19.5	1	4	183	16	0.99
19	6/1/2011	Buffalo Creek	90,000	18.2-19.5	2	4	88	16	0.98
20	6/1/2011	Buffalo Creek	90,000	18.2-19.5	1	4	89	16	0.99
21	6/1/2011	Buffalo Creek	90,000	18.2-19.5	0	-	121	16	1.00
22	6/1/2011	Buffalo Creek	90,000	18.2-19.5	2	4	70	16	0.97
23	6/1/2011	Buffalo Creek	90,000	18.2-19.5	2	4	115	16	0.98
24	6/1/2011	Buffalo Creek	90,000	18.2-19.5	2	4	29	16	0.93
				Average	**1.25**	**4**	**120**	**16**	**0.98**
				Total	**10**		**960**		
1	6/3/2011	Buffalo Creek	75,000	18.2-19.5	1	3	19	17	0.95
4	6/3/2011	Buffalo Creek	75,000	18.2-19.5	0	-	29	13	1.00
5	6/3/2011	Buffalo Creek	75,000	18.2-19.5	3	3	37	17	0.93
8	6/3/2011	Buffalo Creek	75,000	18.2-19.5	1	3	27	17	0.96
9	6/3/2011	Buffalo Creek	75,000	18.2-19.5	0	-	83	17	1.00
10	6/3/2011	Buffalo Creek	75,000	18.2-19.5	1	3	29	13	0.97
11	6/3/2011	Buffalo Creek	75,000	18.2-19.5	0	-	49	17	1.00
12	6/3/2011	Buffalo Creek	75,000	18.2-19.5	0	-	78	17	1.00
				Average	**0.75**	**3**	**43.9**	**16**	**0.98**
				Total	**6.75**		**351**		

Appendix 2. Presence of fish species captured in Buffalo Creek and Pine Creek during electrofishing surveys conducted in 2010 and 2011.

	Buffalo Creek				Pine Creek			
	Strawbridge Rd Bridge		Foot bridge on Rt 1003		Darling Run Access		Ansonia Bridge	
	2010	2011	2010	2011	2010	2011	2010	2011
American eel	+	+	+	+		+		+
Banded darter	+	+	+	+	+	+	+	+
Blacknose dace	+	+			+	+	+	+
Bluegill			+	+	+		+	+
Bluntnose minnow		+	+	+		+		+
Central Stoneroller	+		+		+		+	
Chain Pickerel			+					
Common carp				+				
Common Shiner		+	+			+		+
Creek chub							+	
Creek chubsucker			+					
Cutlips Minnow	+	+	+	+	+	+	+	+
Fallfish	+	+	+	+	+	+	+	+
Green Sunfish								
Greenside Darter	+	+	+	+	+	+	+	+
Longnose dace	+	+	+	+	+	+	+	+
Margined Madtom	+	+	+	+	+	+	+	+
Mimic shiner		+		+		+		+
Northern hogsucker	+	+		+	+	+	+	+
Pearl dace		+			+			
Pumpkin Seed		+	+	+				
Redbreast Sunfish		+						
Rock Bass		+	+		+		+	
Rosyface shiner	+	+			+	+	+	+
Rosyside dace				+				
Satinfin Shiner			+					
Shield Darter	+	+	+	+	+	+	+	+
Smallmouth bass	+	+	+	+		+	+	+
Spotfin Shiner		+		+				+
Spottail shiner	+	+	+	+	+	+	+	+
Swallowtail shiner	+		+		+	+	+	+
Tessellated darter	+	+	+	+	+	+	+	+
White sucker	+	+	+	+	+	+	+	+
Yellow bullhead			+	+				